Dipole & Quadrupole Models

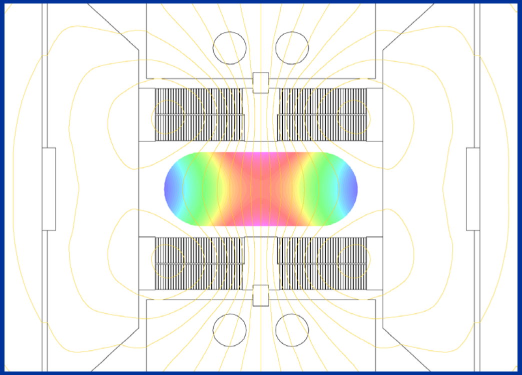
LARP Collaboration Meeting

February 26-27, 2004

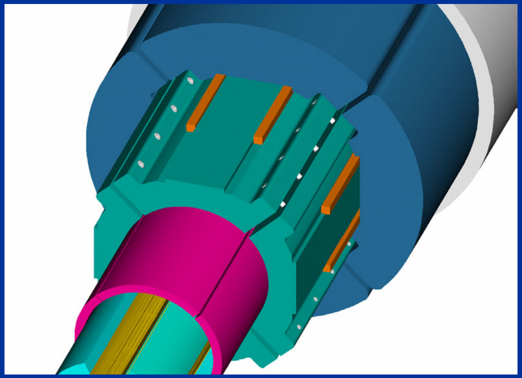
Gian Luca Sabbi

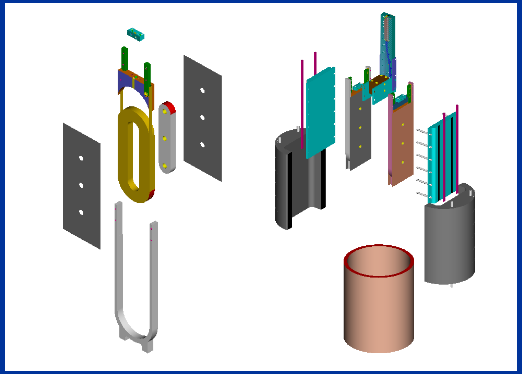
Technological Models

Split-coil/HD1 dipole

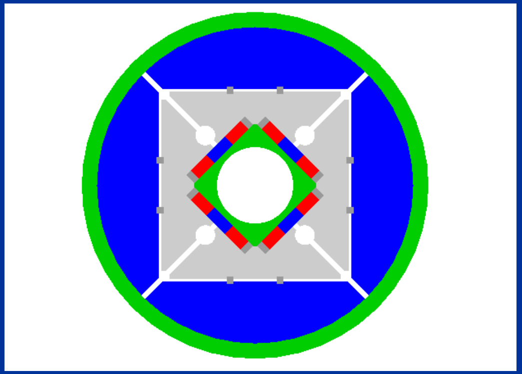


Quadrupole Structure





SM (common coil)



SM Quadrupole

Motivation / Approach

Pre-requisites to proceed with detailed magnet designs and prototypes:

- Demonstration of fundamental magnet performance requirements
- Experimental feedback on basic design and technology options
- Integrated understanding of AP, magnet and radiation issues

⇒ **Focus on technological models for near-term LARP R&D**

Guidelines for model magnet development:

- Concentrate on fundamental R&D issues
- Provide feedback in a cost-effective and timely manner
- Incremental – start simple, each step builds on previous ones

Separation Dipole Model

Two design approaches:

1. No conductor at the midplane
2. <u>No material at the midplane</u>

<u>R&D issues:</u>

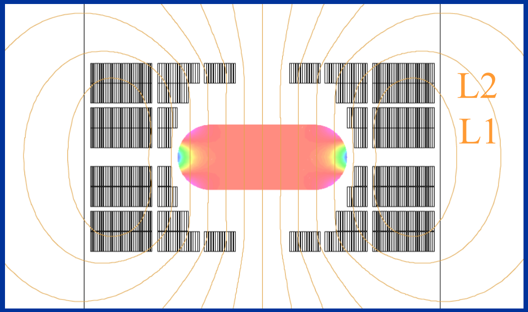
1. Low density spacer (support w/min heat)
2. <u>Coil mech support against vertical forces</u>

Early feedback using HD1 coils and the BNL proposed structure

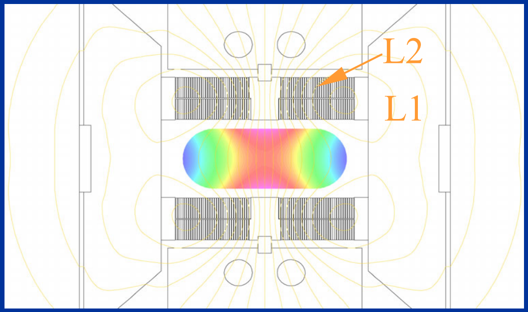
Dipole Field, Energy and Forces

Forces are given for one quadrant at short sample

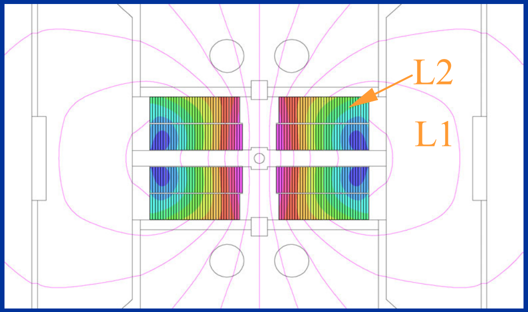
Magnet design	$B_{pk}^{(ss)}$ (T)	$B_0^{(ss)}$ (T)	Stored En. (MJ/m)	F_x - Tot (MN/m)	F_y - Tot (MN/m)	F_y – L1 (MN/m)	F_y – L2 (MN/m)
LARP/HD	16.0	14.8	3.9	3.4+6.7	-6.6	-0.6	-6.0
LARP/HD1	14.7	10-12	0.7	4.9	-0.4	1.0	-1.4
HD1 baseline	16.1	16.7	0.6	4.9	-1.7	-0.1	-1.6



LARP/HD



LARP/HD1



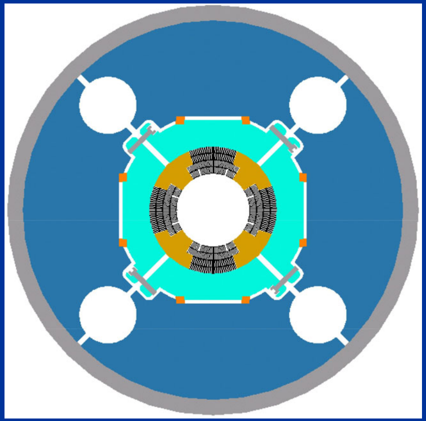
HD1 baseline

- LARP/HD1 forces are a good representation of the first two layers of LARP/HD
- LARP/HD has very large vertical force, and no compensation between layers

IR Quad Models

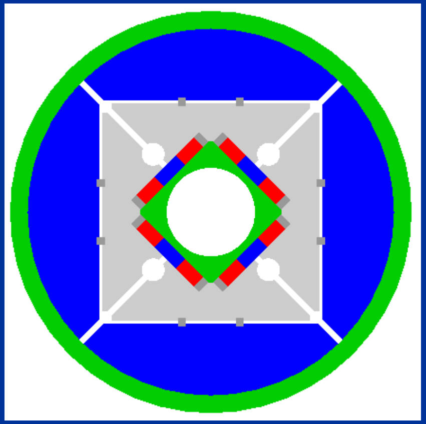
Cos2θ Quad

- *Conductor R&D (D. Dietderich)*
- *Support structure (S. Caspi)*



SM Quad

- Based on SM (subscale) coils
- *Magnet design (P. Ferracin)*
- Initial focus on support/assembly
- *SM Quad studies*
- *Racetrack quad evaluation*



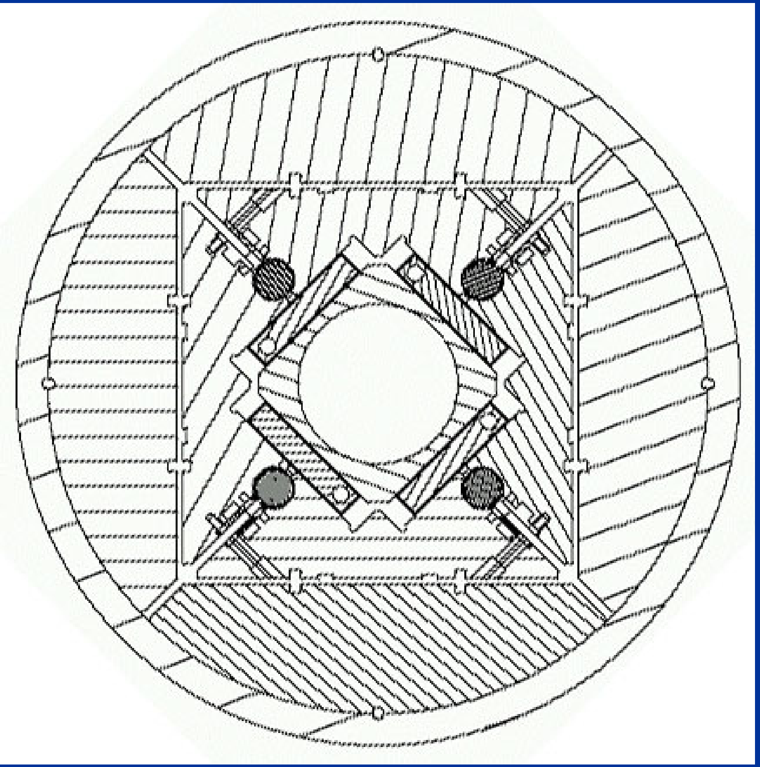
SM Quad Studies

General application:

⇒ Mechanical support structure optimization
⇒ Longitudinal support issues, 3D pre-stress
⇒ Stress limits, pre-stress options
⇒ Validation of mechanical analysis models
⇒ Assembly/alignment with bladder & keys
⇒ Coil fabrication tolerances/reproducibility
⇒ Field correction (coil & magnetic shims)
⇒ Thermal and quench protection studies

Racetrack quad specific:

⇒ Internal bore support requirements
⇒ Coil support/prestress wedges

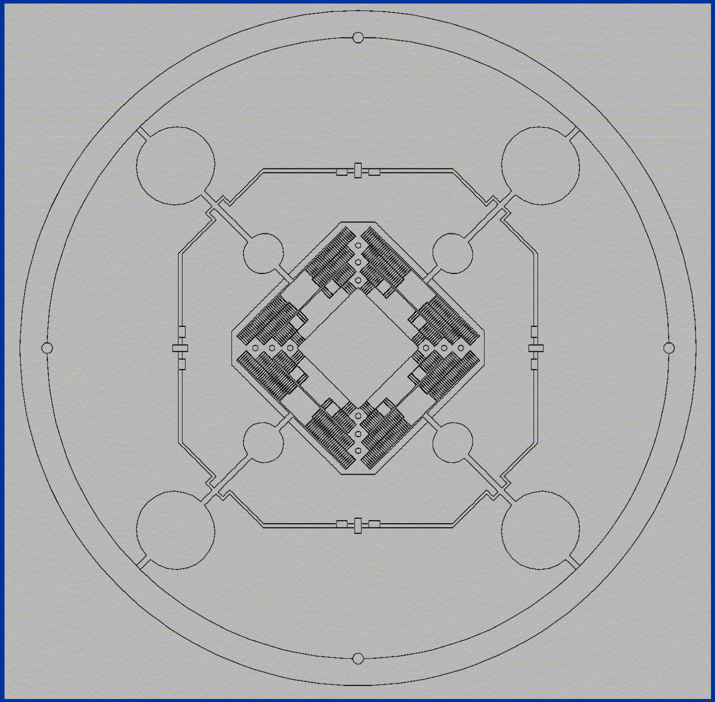


Racetrack Quads for the LHC?

Main features:

- Two double-layer racetracks/quadrant
- (One) flat cable, simple coil ends
- Bladder & key support
- HD1-type longitudinal support rods
- Compatible w/available shell and yoke
- No conductor at the midplane
- 90 mm aperture at the quad main axes

- Could meet basic LHC requirements
- FY04: SM model data, design optim.



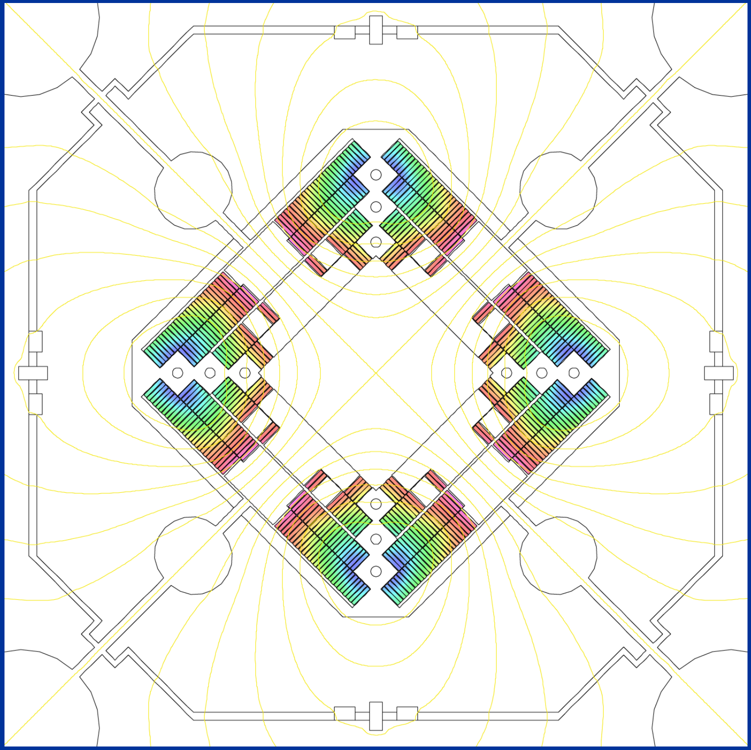
Coil Module Design

Design features:

- Cable: 20 strands, 0.8 mm, 16+49 turns
- HD1-type layer transitions
- Minimum end radius 12 mm
- Separation of high field/stress points
- Cooling channels at the mid-plane

Design issues:

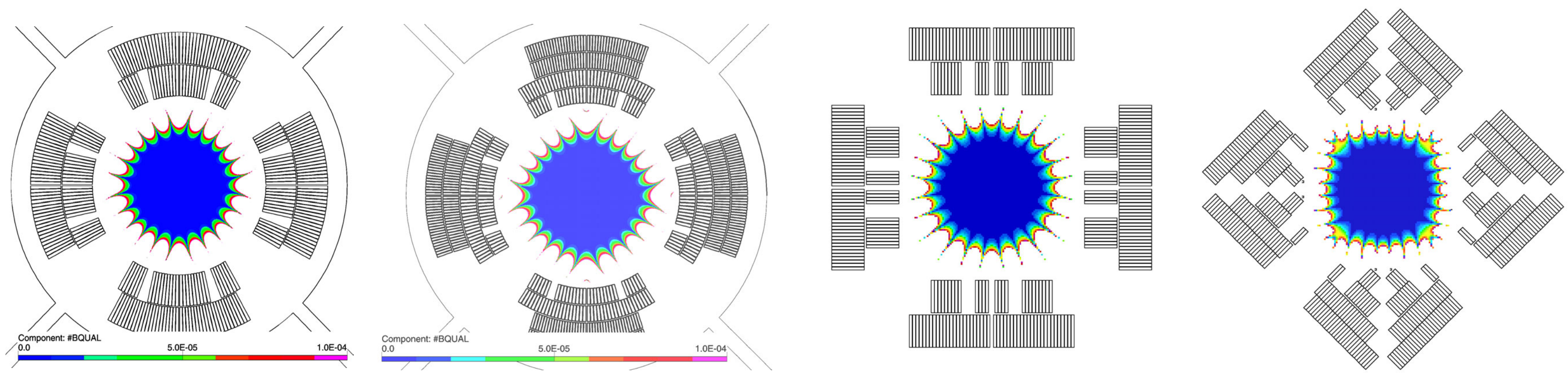
- Bore plate support requirements
- Stress concentration at mid-plane wedge
- Aperture restriction at the pole
- Assembly and alignment



Coil Performance Comparison

Parameter	Cos2θ (2L)	Cos2θ (4L)	Block (2L)	Racetrack (4L)
G_{ss} (T/m) (*)	245	265	230	234
$b_{6,\,10,\,14,\,18}$ @ 22 mm	< 0.05	< 0.05	< 0.05	< 0.07
Inductance (mH/m)	4.9	23.7	4.8	14.2
$J_{cu}^{(ss)}$ (A/mm^2)	1.5	1.4	1.5	1.5
SC area (cm^2)	46.5	48.5	47.8	51.4

(*) J_c (12T, 4.2K) = 2.4 kA/mm^2 and T_{op} = 1.9 K; actual yoke geometry; 90 mm aperture at the main quadrupole axes



Cos2θ (2L) Cos2θ (4L) Block (2L) Racetrack (4L)

Performance Comparison - Comments

Design parameters were selected for consistency in coil geometry comparison

Improvements of the racetrack quad performance may derive from:

- Higher J_c (assumed 2.4 kA/mm^2 @ 12 T, 4.2 K); Higher J_{cu}
- Increased cable width, larger coil area
- Further coil geometry optimization, "reverse grading"
- Use of iron to compensate for harmonics (saturation effects increase)

Racetrack design scales well with larger apertures:

- Separation of high field/stress points
- Flexibility on cable width (no keystoning, low aspect ratio)

Actual magnet performance determined by radiation, stress and quench limits

Actual field quality determined by fabrication tolerances, corrector strength

Subscale Models

FY04:

- New instrumentation
- Coupled thermal/stress analysis during quench
- Conductor development with SM cable

FY05-FY06:

- Rad hard materials testing (insulation, epoxy)
- Test new cable designs
- …
- Start study of length scaling issues using a "long subscale"?

R&D on Long Nb_3Sn Magnets

Erice 2003: start investigating length scaling issues early on
Need small cross-section for cost reduction ⇒ use "subscale"

R&D issues:

- Stress control during coil reaction, cable R&D (anneal), pole design
- Handling of reacted coils
- Segmented support shells (He containment? Welded, thin sheets,…)
- Design/fabrication/test of long bladders; key insertion issues
- Magnet alignment

Need collaborative effort for best use/implementation of facilities:
winding, reaction, impregnation, assembly, test

R&D Targets (Erice 2003)

Objective: Demonstrate the technology base required for future LHC upgrades

Guidelines: Concentrate on one (few) fundamental R&D issues at a time
Prescribe performance parameters, not design/technology choices

- Basic features:
  - #1: Bore field ≥ 18 T with ≥ 5 mm clear bore
  - #2: Bore field ≥ 16 T with ≥ 30 mm clear bore (cold bore included)
  - #3: Bore field ≥ 14 T with ≥ 3 m magnetic length
- Dipoles (B_0^{nom}=14 T, harmonics as measured at 10 mm *physical* radius):
  - #4: All central harmonics ≤ 3 units at B_0^{nom}
  - #5: All central harmonics ≤ 10 units from 0.1 B_0^{nom} to B_0^{nom} @ 0.5 T/min
- Quadrupoles (G^{nom}=200 T/m, harm. as measured at 20 mm *physical* radius)
  - #6: All central harmonics ≤ 3 units at G^{nom}

Summary

<u>*Focus on technological models for near term LARP R&D:*</u>

- A separation dipole structure test using the HD1 coils
- SM quads for fast feedback on many design/technology issues
- Instrumented support structure to check basic performance
- Standard SM coils for material, conductor, quench studies
- A "long subscale" to start addressing magnet length issues

Integrated efforts (magnets, accelerator physics, radiation) needed to investigate the main design/technology options

R&D targets to help guide the development and track progress